

1 What is claimed is:

2 1. A method for generating digital filters for tuning a hearing aid to
3 enhance hearing ability comprising:

4 providing first digital data for a tolerance range for a target response
5 curve representative of said enhanced hearing ability of sound level versus
6 frequency;

7 providing second digital data representing an initial response curve of
8 an initial hearing ability to be enhanced of sound level versus frequency;

9 comparing said first digital data to said second digital data and
10 determining whether said initial response curve is within said tolerance range;
11 and

12 if said initial response curve is not within said tolerance range,
13 iteratively generating digital audio filters, applying said digital audio filters to
14 said second digital data to generate third digital data for a compensated
15 response curve, and automatically optimizing the frequency, amplitude and
16 bandwidth of said digital audio filters until said compensated response curve
17 is within said tolerance range or a predetermined limit on the number of digital
18 audio filters has been reached, whichever occurs first.

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20 2. A method according to Claim 1, wherein said step of iteratively
21 generating digital audio filters is performed by iteratively generating second
22 order filters.

24 3. The method of Claim 1 wherein said initial response curve is an
25 audiogram.

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27 4. A method for generating a set of second order filters to tune a hearing
28 aid to enhance hearing ability comprising:

29 providing first digital data for a tolerance range for a target response
30 curve representative of said enhanced hearing ability of sound level versus
31 frequency;

32 providing second digital data representative of an initial response curve
33 of an initial hearing ability to be enhanced of sound level versus frequency;

34 comparing said first digital data to said second digital data and
35 determining whether said initial response curve is within said tolerance range;
36 and

37 if said initial response curve is not within said tolerance range,
38 generating a set of filters to tune said hearing aid by performing the following
39 optimizing steps iteratively,

40 digitally processing said second digital data to determine an n^{th}
41 set of initial parameters for an n^{th} peak in said actual initial
42 curve where said initial response curve is not within said
43 tolerance range, including a frequency, and amplitude and a
44 bandwidth for said peak, where n is the number of an iteration of
45 said optimizing steps, digitally generating a compensating n^{th}
46 filter from said n^{th} set of initial parameters, applying said n^{th} filter

47 to said second digital data and modifying said n^{th} set of initial
48 parameters to determine an n^{th} set of optimum parameters for
49 said compensating n^{th} filter, to generate third digital data for an
50 nth interim compensated response curve of sound level versus
51 frequency, processing said third digital data to determine
52 whether said nth interim compensated response curve is within
53 said tolerance range, if said nth interim compensated response
54 curve is not within said tolerance range, performing another
55 iteration of said optimizing steps until said interim compensated
56 response curve is within said tolerance range or a
57 predetermined limit on the number of filters has been reached,
58 whichever occurs first.

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60 5. A method of Claim 4, wherein said step of digitally generating a
61 compensating nth filter is performed by digitally generating a second order
62 filter.

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64 6. The method of Claim 4, wherein said initial response curve is an
65 audiogram.

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67 7. A method for generating filters for tuning a hearing aid to enhance
68 hearing ability comprising:
69 providing first digital data for a tolerance range for a target response
70 curve representative of said enhanced hearing ability of sound level
71 versus frequency;
72 providing second digital data for an initial response curve of said hearing
73 ability to be enhanced of sound level versus frequency;
74 comparing said first digital data to said second digital data and
75 determining whether said initial response curve is within said tolerance
76 range; and
77 if said initial response curve is not within said tolerance range,
78 generating a set of compensating filters by performing the following
79 single filter optimizing steps iteratively,
80 digitally processing said second digital data to determine an n^{th} set
81 of initial parameters for an n^{th} peak in said initial response curve
82 where said initial response curve is not within said tolerance range,
83 including a frequency, an amplitude and a bandwidth for said peak,
84 where n is the number of an iteration of said optimizing steps,
85 digitally generating a compensating n^{th} filter from said n^{th} set of initial
86 parameters,
87 applying said n^{th} filter to said second digital data and modifying
88 said n^{th} set of initial parameters to determine an n^{th} set of

89 optimum parameters for said n^{th} filter, to generate third digital
90 data for an n^{th} interim compensated response curve of sound
91 level versus frequency;
92 if $n > 1$, performing the following joint filter optimizing steps iteratively and
93 cyclically,
94 generating fourth digital data for interim computed response curves
95 in which for each joint filter optimizing iteration one of said n filters
96 is absent, and then performing said single filter optimization steps
97 utilizing said fourth digital data to generate fifth digital data for an
98 updated interim response curve,
99 digitally processing said fifth digital data to determine whether the
100 most recent of said joint filter optimizing iterations has resulted in a
101 change in said updated interim response curve greater than a
102 predetermined amount of change, and if so continuing to perform
103 said joint filter optimizing steps;
104 processing said fifth digital data to determine whether said n^{th}
105 interim compensated response curve is within said tolerance range,
106 and if not,
107 performing another iteration of the foregoing steps until said
108 interim compensated response curve is within said tolerance
109 range or a predetermined limit on the number of filters has
110 been reached, whichever occurs first,
111 but if so, ceasing performance of further iterations.

1 8. A method according to Claim 7, wherein said step of digitally
2 generating a compensating n^{th} filter is performed by digitally generating a
3 second-order filter.

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5 9. The method of Claim 8 wherein said initial response curve is an
6 audiogram.

1 10. A method for generating filters for tuning a hearing aid to enhance
2 hearing ability of an individual comprising:
3 fitting said hearing aid to said individual;
4 connecting said hearing aid to a source of audio digital signals;
5 providing said individual with a device to generate indication signals at
6 will;
7 generating and providing a first series of audio digital signals to said
8 hearing aid, each signal in said first series of signals having a selected
9 frequency and multiple power levels;
10 receiving said indication signal during said generation of a signal of a
11 selected frequency indicative of said individual hearing said selected
12 frequency;
13 providing a digital audio processing unit in said hearing aid for
14 processing received audio digital signals and providing processed audio

15 digital data, including applying digital audio filters for tuning said hearing
16 aid characterized by coefficients in algorithms applied to said received
17 audio digital signals to effect said digital audio filters;
18 providing a digital computer connected to receive said first series of
19 audio digital signals and said indication signals to generate digital data
20 representative of said individual's hearing ability using said hearing aid
21 without filters determined from said first series of signals, said computer
22 programmed to determine said coefficients for digital filters for tuning
23 said hearing aid and providing said coefficients to said digital audio
24 processing unit in said hearing aid.

1 11. A method according to Claim 10, wherein said digital computer is
2 programmed to determine said coefficients by
3 providing second digital data for a tolerance range for a target response
4 curve ability of representative of said individual's enhanced hearing
5 ability of sound level versus frequency;
6 providing first digital data representative of an initial response curve of
7 said individual's hearing ability of sound level versus frequency;
8 comparing said second digital data to said first digital data and
9 determining whether said response curve is within said tolerance range;
10 and
11 if said response curve is not within said tolerance range,

12 iteratively generating coefficients for digital audio filters,
13 applying digital audio filters determined by said coefficients to said
14 first digital data to generate third digital data for a compensated
15 response curve, and
16 automatically optimizing said coefficients by optimizing the
17 frequency, amplitude and bandwidth of said digital audio filters until
18 said compensated response curve is within said tolerance range or
19 a predetermined limit on the number of digital audio filters has been
20 reached, whichever occurs first.

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12. The method of Claim 11 wherein said computer receives said first
series of signals and indication signals generated by said device to generate
said first digital date.

13. The method of Claim 11 wherein said first digital data is an audiogram.

1 14. An apparatus for generating filters for tuning a hearing aid for use by
2 an individual, comprising:
3 a source of first audio digital data;
4 a digital audio processing unit in said hearing aid for processing said first
5 audio digital data and providing processed audio digital data to said
6 individual, including applying digital audio filters for tuning said hearing

7 aid characterized by coefficients in algorithms applied to said first audio
8 digital data to effect said digital audio filters;
9 a device for generating indication signals indicative of said individual
10 receiving said first audio digital data; and
11 a digital computer connected to receive said first audio digital data and
12 said indication signals, said digital computer programmed to determine
13 said coefficients for digital filters for tuning said hearing aid and provide
14 said coefficients to said digital audio processing unit.

1 15. An apparatus according to Claim 14, wherein said digital computer is
2 programmed to generate second digital data representative of said individual
3 hearing ability when using said hearing aid without filters determined from
4 said first audio digital data and said indication signals and to determine said
5 coefficients by
6 providing third digital data for a tolerance range for a target response
7 curve of enhanced hearing of sound level versus frequency;
8 providing said second digital data, wherein said second digital data
9 represents an initial response curve of hearing ability of sound level
10 versus frequency;
11 comparing said third digital data to said second digital data and
12 determining whether said initial response curve is within said tolerance
13 range; and
14 if said initial response curve is not within said tolerance range,

15 iteratively generating coefficients for digital audio filters,
16 applying digital audio filters determined by said coefficients to said
17 second digital data to generate fourth digital data for a
18 compensated response curve, and
19 automatically optimizing said coefficients by optimizing the
20 frequency, amplitude and bandwidth of said digital audio filters until
21 said compensated response curve is within said tolerance range or
22 a predetermined limit on the number of digital audio filters has been
23 reached, whichever occurs first.

1 16. A method for generating digital filters for tuning a hearing aid to

2 enhance hearing ability, comprising:

3 providing first digital data for a tolerance range for a target response

4 curve representative of said enhanced hearing ability of sound level

5 versus frequency;

6 providing second digital data representing an initial response curve of an

7 initial hearing ability to be enhanced of sound level versus frequency;

8 comparing said first digital data to said second digital data and

9 determining whether said initial response curve is within said tolerance

10 range; and

11 if said initial response curve is not within said tolerance range,

iteratively generating digital audio filters to compensate said initial response curve,

applying said digital audio filters to digital signals representative of received sound to generate third digital data, converting said third digital data to an analog signal and providing said analog signal to a speaker in said hearing aid,

generating fourth digital data representative of an enhanced response curve of hearing ability of sound level versus frequency;

comparing said first digital data to said fourth digital data and determining whether said enhanced response curve is within said tolerance range; and

automatically optimizing the frequency, amplitude and bandwidth of said digital audio filters until said enhanced response curve is within said tolerance range or a predetermined limit on the number of digital audio filters has been reached, whichever occurs first.

17. A method according to Claim 16, wherein said step of iteratively generating digital audio filters is performed by iteratively generating second-order filters.

18. The method of Claim 16 wherein said initial response curve is an audiogram.

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8 19. The method of Claim 18 wherein said enhanced response curve is an
9 audiogram.

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11 20. A method for generating total log-integral metric digital data for
12 characterizing the perceived performance of a hearing aid, comprising the
13 steps of:

14 providing first digital data for N samples for a desired response curve of
15 acceptable hearing ability of sound level versus frequency;

16 providing second digital data representing N samples for an initial
17 response curve of sound level versus frequency; and

18 generating total log-integral metric data according to the formula:

$$M = \sum_{i=1}^{N-1} \log_{10} \left(\frac{f_{i+1}}{f_i} \right) \left[\frac{|S(f_i)_{dB} - D(f_i)_{dB}| + |S(f_{i+1})_{dB} - D(f_{i+1})_{dB}|}{2} \right]$$

19 where:

20 M is the total log-integral metric,

21 f is the frequency,

22 D is the first digital data,

23 S is the second digital data, and

24 N is the number of samples of first digital data and of second
25 digital data.